



**FSF CFIT Task Force
Aircraft Equipment Team**

Final Report

Presented by

Capt. D.E. Walker
Chairman

Table of Contents

Introduction	3
CFIT Aircraft Equipment Team	4
Executive Summary	5
Report Format	6
CFIT Accident Data Base	7
Chart Presentation	8
Ground-proximity Warning System (GPWS)	10
Updating of GPWS Equipment	10
Use of Terrain Data to Improve GPWS Capability and Performance	11
Use of GPWS in Domestic as Well as in International Operations	12
European Organization for Civil Aviation Engineers (EUROCAE) Working Group WG 44, Ground-collision Avoidance System (GCAS)	13
Approach Procedure Design	14
Vertical Navigation	17
Barometric Altimetry	17
Three-pointer and drum-pointer altimeters	17
QNH/QFE	18
Altimeter setting units	19
Radio Altimetry	20
Altitude callout	20
Approach waypoints	21
Use of the Global Navigation Satellite System (GNSS)	23
Excessive-bank-angle Warning	25
Head-up Display (HUD)	27
Enhanced and Synthetic Vision	28
Minimum Safe Altitude Warning System (MSAW)	29
Visual Approach Slope Indicator System (VASIS)	30
Communication Blocking	31
Conclusions	32
Appendices	

Introduction

The Controlled-flight-into-terrain (CFIT) Aircraft Equipment Team, formed as part of a Flight Safety Foundation (FSF)-led industrywide CFIT accident reduction effort, has completed its mandate. This report summarizes the objectives achieved and presents proposals for action by the CFIT Steering Committee.

The CFIT Aircraft Equipment Team focused on aircraft equipment as a means of reducing the risk of CFIT accidents. Membership included representatives of industry, regulators, research organizations and the International Civil Aviation Organization (ICAO). Three full meetings of the team were held. Various subgroup meetings were held on an *ad hoc* basis. Meeting reports have been distributed to the members.

The team focused on the assignment of priorities for action. The time frame for completion of the recommendations is five years. A consensus was achieved for all decisions.

CFIT Aircraft Equipment Team

Name	Affiliation
Capt. M. Aziz	Middle East Airlines, Lebanon
Capt. T. Baberg	Lufthansa German Airlines
D. Bateman	AlliedSignal, United States
Capt. C. Bechet	Avions de Transport Regional (ATR), France
X. Chazelle	Dassault Électronique, France
K. Darby	FlightSafety International, Canada
J.F. Desmoulins	Airbus Industrie, France
J.A. Diaz de la Serna	International Civil Aviation Organization, Canada
Capt. D. Flemming	British Airways, United Kingdom
P. Giordano	FlightSafety International, Canada
S. Hall	British Airways AERAD, United Kingdom
J. Hart	Air Canada
Dr. R. Khatwa	National Aerospace Laboratory (NLR), Netherlands
T. Lively	Bombardier Inc., Canada
J.F. Manfroy	Dassault Électronique, France
P. Mayes	Bureau of Air Safety Investigation, Australia
M. Moon	General Electric Co. (GEC) Marconi Avionics, United Kingdom
J. Moore	Smiths Industries, United Kingdom
B.L. Perry	International Federation of Airworthiness (IFA) Technical Committee, United Kingdom
Capt. R.T. Slatter	International Civil Aviation Organization, Canada
B. Spindler	Direction Générale de l'Aviation Civile/Service Technique de la Navigation Aérienne DGAC/STNA, France
H. Thomas	Honeywell Inc., United States
Capt. T. Van Heerden	South African Airways
Capt. D.E. Walker (Chairman)	Aviation Consultant, Canada
K. Wilson	Transport Canada
Capt. P. Woodburn	British Airways, United Kingdom
Capt. T. Young	Air Line Pilots Association, United States

Executive Summary

This report summarizes the work of the FSF CFIT Task Force's Aircraft Equipment Team. The tasks defined fall into the following broad categories:

- CFIT accident data base;
- Standards for procedural design and chart production;
- Recommended practices/systems;
- Ground-collision warning systems;
- Recognition of proximity to terrain;
- Accurate vertical navigation;
- Accurate horizontal navigation;
- Understanding factors involved in CFIT; and,
- Potential systems for future consideration.

A consensus was achieved for the recommendations concerning each item. Our recommendations were weighted within these categories according to the estimated cost/benefit ratio. In addition to our recommendations, and ICAO actions, it is important that individual States review their regulations in concert with ICAO action.

Report Format

The reports on items under specific headings or subheadings are organized in the following manner:

- a) Title or subtitle;
- b) Problem statement: Brief overview of the problem;
- c) Recommendations: FSF CFIT Task Force recommendations;
- d) Results: What is being accomplished;
- e) Action: Action to be taken by the CFIT Task Force; and,
- f) References: Supporting documents, some of which are located in the Appendices.

CFIT Accident Data Base

Problem statement

The team has used the accident data base to focus on those areas showing the greatest need. Much of the existing accident data base provides only partial coverage of CFIT accidents because it concentrates on larger aircraft. The data originally published by ICAO in 1992 covered all turbine-engine aircraft in commercial and general aviation operations.

Recommendations

As a matter of urgency, improve the means of collecting and disseminating CFIT accident data. Accident investigation agencies are urged to forward their findings to ICAO in the proper format and in a timely manner. This is particularly critical for the nonheavy jet category.

Develop a means to measure the success of the CFIT prevention program.

Results

ICAO and others have continued to collect and refine CFIT data for all turbine-engine aircraft. These agencies report that the CFIT accident data are often incomplete and usually very tardy. The data are collected and refined in specific areas of interest.

Action

All concerned should continue to monitor and record CFIT occurrences.

The CFIT Steering Committee will require a means to measure the effect of the implementation of the CFIT prevention program.

References

CFIT Accidents and Risk for U.S. Airlines Large Commercial Jets (Appendix A).

Corporate, Regional and Air Taxi CFIT Accidents 1989 to 1994 (Appendix B).

Report. R. Khatwa, National Aerospace Laboratory (NLR) Flight Division, Netherlands (Appendix D).

Maurino, Capt. D. "Human Factors and Organizational Issues in Controlled Flight into Terrain (CFIT) Accidents." Eighth International Symposium on Aviation Psychology, Ohio State University, U.S. April 1995.

Chart Presentation

Problem statement

Navigation errors are a principal cause of CFIT accidents. Improved charts are seen as a major resource in the reduction of navigation errors.

The transition to and from en route charts to departure/arrival charts was of concern and had not been addressed, nor has the question of applying contours and color tinting to other charts. The problem of scale presentation has to be overcome. These items need to be addressed both within ICAO and by the various panels.

Instrument approach charts, standard instrument departure (SID) and standard terminal arrival (STAR) charts often contain a considerable quantity of vital information essential for the safe conduct of flights, in the vicinity of airports and in close proximity to terrain. These charts are frequently complex, with densely packed information. Presentation can result in chart clutter that may cause the pilot to overlook vital information. Errors of extraction and interpretation are known to have contributed to a number of accidents and many incidents. Chart producers should pay particular attention to the need to eliminate clutter and for the need to display only information essential for the safe and proper execution of required procedures. All other related secondary information should be removed to a separate panel or page.

Recommendations

Colored contours should be used to present either terrain or minimum flight altitudes on instrument approach charts.

It is also recommended that ICAO re-examine the specifications for instrument approach charts in ICAO Annex 4, Chapter 11. The objective of this re-examination should be the inclusion of Standards requiring either a presentation showing terrain contours or a presentation including minimum flight altitudes. Further Standards should require the use of brown hypsometric tinting in terrain contour presentations and green tinting in minimum flight altitude presentations. Both presentations should provide for the use of white for the level of the aerodrome to provide contrast and aid the interpretation of the chart. Significant spot heights should be shown on the terrain contour presentation. The terrain profile below an approach should also be shown.

Results

In March 1995 the ICAO Air Navigation Commission (ANC) tasked the Secretariat to review the adequacy of the Annex 4 *Aeronautical Charts* provisions regarding: the portrayal of terrain contours; the portrayal of minimum flight altitudes; use of color tinting; and the provision of the terrain profile under the final approach segment. Major commercial providers of charts are already using the recommended contour and color tinting systems.

Action

Re-emphasize the importance attached to the recommendation for colored contours and re-examination of instrument approach chart specifications to ICAO and to all providers and users.

Recommend that the Society of Automotive Engineers (SAE) G-10 Committee address the problems raised about the role of navigation errors in CFIT accidents.

Inform all State Civil Aviation Authorities and operators of the advantages and availability of instrument approach procedure charts with contour presentations and of the recommendations to ICAO and SAE.

Reference

KLM fax dated 19 August 1994 (Appendix G).

Ground-proximity Warning System (GPWS)

Updating of GPWS Equipment

Problem statement

The Aircraft Equipment Team is aware that the continued use of older unmodified GPWS equipment results in the persistent experience of false and nuisance GPWS warnings that could be avoided if the earlier standard of equipment was taken out of service and all equipment was modified to the latest standard available. These unnecessary, and now avoidable warnings, contribute adversely to the acceptance of the GPWS and the prompt reaction required to GPWS warnings by the flight crew.

Recommendation

Early GPWS equipment should be taken out of service and replaced by modern equipment or updated, where modifications are available. Such action would decrease the number of unwanted warnings experienced and thus increase the integrity and reliability of the GPWS and the likelihood of timely pilot response.

Results

In March 1995 the ICAO ANC stressed the need for the provision of adequate GPWS equipment.

The minimum requirements in the proposed U.S. Federal Aviation Administration (FAA) Technical Standard Order (TSO)-C92c would add to the existing requirements: a requirement for an aural message to identify the reason for a warning; call for the inclusion of airspeed logic to improve warning time; and a requirement for altitude callout in nonprecision approaches. These features are all available in currently produced equipment. The requirements of the proposed TSO-C92c are considered an example of the minimum adequacy of GPWS equipment.

ICAO has adopted amendments to Annex 6, Parts I and II, that extend the requirement to carry GPWS to all turbine-engine airplanes in international commercial/corporate/private operations where the maximum certificated takeoff mass is in excess of 5,700 kilograms (12, 500 pounds) or which are authorized to carry more than nine passengers. These extended requirements, based on an FSF CFTT Task Force recommendation, are effective from 1 January 1999. The amendments include specification of the minimum functions of the GPWS. These are the original functions dating from the 1970s that have not previously been established as ICAO Standards, and some have been intentionally deactivated in GPWS installations in the past.

Action

Re-emphasize to ICAO the importance of taking out of service or updating early GPWS equipment.

Stress to civil aviation authorities and operators the importance of taking older and less effective GPWS equipment out of service.

References

Annex 6, *Operation of Aircraft*, Part I. *International Commercial Air Transport Aeroplanes*, Sixth Edition, paragraph 6.15. July 1995.

Annex 6, *Operation of Aircraft*, Part II. *International General Aviation Aeroplanes*, Fifth Edition, paragraph 6.9. July 1995.

ICAO letter to States and international organizations, reference AN 11/37-95/64, 11 August 1995.

U.S. Federal Aviation Administration (FAA) proposed TSO-92c, *Airborne Ground Proximity Warning Equipment*.

Use of Terrain Data to Improve GPWS Capability and Performance

Problem statement

The capability now exists to use terrain data to provide predictive ground-proximity warning capabilities and to provide a visual display of the terrain to the flight crew. This is demonstrated in the enhanced GPWS being developed. Although a limited amount of terrain data are currently available to the flight crew from the aircraft charts and maps, the increasing availability of worldwide terrain data, in digital form, has opened opportunities for many new cockpit systems. ICAO has established requirements for use of the World Geodetic System 1984 (WGS-84) from the beginning of 1998.

Recommendation

Such developments should be actively supported.

Results

In March 1995 the ICAO ANC noted the support of the CFIT Task Force for the further development and introduction of terrain data base proximity warning systems; stressed the need for an accurate worldwide terrain data base; and urged States to facilitate the release of terrain data in digital form of suitable accuracy and geodetic reference for use in civil aviation, in accordance with Article 28c of the Convention on Civil Aviation.

There is a need for development of specifications for a format and parameters for a universal digital terrain data base.

Recommendation

Radio Technical Commission for Aeronautics (RTCA) and European Organization for Civil Aviation Engineers (EUROCAE) are asked to establish a joint working group to define an international specification that details a suitable format and other relevant parameters for a universal digital terrain data base.

Reference

Terrain Data Integrity Requirements (Appendix G).

Use of GPWS in Domestic as Well as in International Operations

Problem statement

The Standards of ICAO Annex 6, Part I, apply to international commercial operations. The new Annex 6, Parts I and II Standards, which take effect 1 January 1999, will apply to both international commercial and to international corporate and private operations. Many States have introduced requirements for GPWS in domestic commercial operations as well as in international operations. Other States have not extended requirements to domestic operations.

The CFIT accident record shows that the greater proportion of CFIT accidents have taken place in domestic operations. It is necessary to persuade civil aviation authorities that have not yet extended requirements to domestic commercial operations, to undertake this extension. Such action is essential if the objective of the CFIT prevention program is to be achieved.

Very few States require the carriage of GPWS in corporate or private operations. Thought must be given to this area by the regulatory authorities because the new ICAO Standards for general aviation, corporate and private operations, come into force on 1 January 1999. Some corporate operators have voluntarily equipped their aircraft with GPWS, and the business aviation community is showing a great interest in CFIT prevention.

Recommendation

All aircraft in commercial and corporate use should be equipped with GPWS, even where these airplanes are used only in domestic operations.

Results

In June 1995, the ICAO Council approved a report for the ICAO Assembly (19 September to 4 October 1995) on CFIT prevention activity. In addition to the report, the Council will present a draft resolution for adoption by the Assembly to urge States to implement the CFIT prevention program and the related ICAO provisions, particularly those concerning the carriage of GPWS, in domestic as well as in international operations.

Action

Every opportunity should be taken to stress to civil aviation authorities and operators the importance of CFIT prevention in domestic operations. Maximum use should be made of the ICAO 31st Assembly Resolution if this is adopted.

Reference

ICAO Assembly, 31st Session, A31-WP/43, 6 July 1995.

European Organization for Civil Aviation Engineers (EUROCAE) Working Group WG 44, Ground-collision Avoidance System (GCAS)

Problem statement

This group is preparing minimum operational performance specifications (MOPS) for ground-collision avoidance systems (GCAS). This document defines, *inter alia*, mandatory and nonmandatory warnings, pull-up/reaction times and acceptable failure rates. Lateral guidance is currently not mandatory. It is expected that Joint Aviation Regulations—Operations (JAR-OPS) and the Joint Transport Service Orders (JTSO) for GPWS will reference the GCAS document.

Recommendations

Preparation of MOPS for a ground-collision avoidance system.

That a coordinated effort be made by the appropriate bodies to establish standards for the ground-collision avoidance system. These efforts are to be correlated with ICAO standards.

Approach Procedure Design

Problem statement

The design of the nonprecision approach was seen by the group as an area where much could be accomplished at little cost. This objective can be met by the simplification of the nonprecision approach, the specification of a stabilized approach and the provision of a nominal three-degree glide path.

Recommendations

General

Nonprecision approach procedures should be constructed, whenever possible, in accordance with established stabilized approach criteria.

It is also recommended that ICAO re-examine the specifications for the design and presentation of nonprecision approach procedures in the *Procedures for Air Navigation Services Aircraft Operations* (PANS-OPS, Doc. 8168), Volume II, Annex 4 *Aeronautical Charts* and associated guidance material. The objective of this re-examination is to require consideration of the stabilized approach; the provision of a final approach fix; and to require the provision of a three-degree approach slope, where compatible with the obstacle environment. The need to show the underlying obstacle clearance profile on these instrument approach charts should also be considered.

Specific

One final approach segment per navigation aid/runway combination;

If a stepped nonprecision approach cannot be avoided, then the intermediate profile-angles should be shown; and,

The position of the start of the final descent path is to be published.

Recommendations to operators

Nothing in ICAO PANS-OPS prevents the immediate introduction by operators of specific nonprecision instrument approach procedures that take into account the recommendations of the CFIT Task Force, and some operators have been doing so for many years. The concept will require the definition of a fix at the position at which the intermediate approach altitude/height intersects the nominal glide path. Proposals for the amendment of PANS-OPS, from the tenth meeting of the ICAO Obstacle Clearance Panel (31 October to 10 November 1994), would introduce optimum descent gradients for some types of nonprecision approaches where currently only the maximum and minimum gradients are specified.

Recommendation to ICAO

Amplify the 1994 recommendation to ICAO as follows:

Nonprecision approach procedures should be constructed, whenever possible, in accordance with established stabilized approach criteria. If a stepped nonprecision approach cannot be avoided, then the intermediate profile-angles should be shown;

There should be one final approach segment per navigation aid/runway combination;

The final approach glide path should be a nominal three degrees where terrain permits; where a steeper glide path is necessary, up to the maximum angle permitted. A continuous descent is preferred to a stepped approach;

The final segment should start 2,000 feet to 3,000 feet (610 meters to 915 meters) above airport elevation;

There should be provision and publication of a fix at the intersection of the intermediate approach altitude/height and the nominal glide path; and,

Nonprecision approach charts should show the descent profile to be flown;

There should be provision for and publication of appropriate altitude/height checks on the glide path; and,

The profile of the terrain beneath the final approach segment should be provided.

Recommendation to Civil Aviation Authorities and Operators

Continue to emphasize to civil aviation authorities and operators the need to improve the safety of nonprecision approaches by use of the stabilized approach, a three-degree glide path, a final approach point and a final approach fix and the urgency for action on this matter.

Results

In March 1995, the ICAO ANC tasked the Obstacle Clearance Panel to take account of the need for a stabilized approach, based on a three-degree glide path and a final approach fix, in the design and presentation of nonprecision approaches.

References

Slatter, R.T. "Thoughts on the Subject of Nonprecision Instrument Approach Procedure Design from the Point of View of the Pilot." 8 April 1994 (ICAO Document).

Slatter, R.T. "Chart Design Revision Could Enhance Safety of Nonprecision Approach and Landing Operations." *ICAO Journal* (May 1994).

Slatter, R.T. "Nonprecision Approaches, Shallow Descent Gradients." CFIT-AET/WP-OPS/1, 15 May 1994.

Slatter, R.T. "Nonprecision Approaches, Stepped Approaches." CFIT-AET/WP-OPS/2, 12 May 1994.

Slatter, R.T. "Multiple Approaches to One Runway Using the Same Aids." CFIT-AET/WP-OPS/3, 12 May 1994.

Information provided by KLM, 19 August 1994 (Report to Committee).

FAA letter dated 11 January 1995 (Report to Committee).

Walker, Capt. D.E. "Operational Approval of Stabilized Instrument Approach Procedures for Flight Management/Guidance System Equipped Aircraft" (Report to Committee).

Walker, Capt. D.E. "Taking the 'Non' out of the Nonprecision Approach" (Appendix F).

Vertical Navigation

Loss of vertical positional awareness is a principal factor contributing to CFIT accidents. Improved indications of both altitude and height above terrain are seen as reducing the risk of a CFIT accident.

Barometric Altimetry

Three-pointer and drum-pointer altimeters

Problem statement

There is ample evidence that pilot misinterpretation of three-pointer and drum-pointer altimeters can lead to CFIT accidents. There is a long documented history of these errors.

Recommendations

All States and operators should be informed of the dangers inherent in the use of three-pointer and drum-pointer altimeters and usage of these altimeters should be discontinued.

ICAO should examine the case for discontinuing the usage of three-pointer and drum-pointer altimeters and should take appropriate action to amend Annex 6 in this respect.

Results

In March 1995, the ICAO ANC tasked the Secretariat to consider the need to limit the use of three-pointer and drum-pointer altimeters. This action is in hand through initial consultation with the ICAO Operations Study Group.

ICAO Annex 6, Parts I, II and III, Sections II and III amendments adopted in 1995 include the addition of a note to the requirement for sensitive pressure altimeters: "Note. Due to the long history of misreadings, the use of drum-pointer altimeters is not recommended." While the addition of a note was possible in a short time scale, this action is not sufficiently comprehensive or strong enough to answer the problem posed by both these types of altimeters.

Action

Stress to civil aviation authorities and operators the dangers inherent in the use of three-pointer and drum-pointer altimeters.

References

Marthinsen, H.F. "The Killer Instrument: The Drum Pointer Altimeter." International Federation of Air Line Pilots' Associations (IFALPA)/Spanish Air Line Pilots' Association Joint Air Safety Seminar, Madrid, Spain, June 1990.

Human Factors Digest No. 6 (Circular 238): 19.

IFALPA. Annex 8, Appendix AIR-B 11 (Cockpit Standardization). November 1993.

QNH/QFE

Problem statement

These very different altitude and height reference systems are in widespread use. The Aircraft Equipment Team was unable to recommend a resolution of these differences. During the past few years many operators have changed to the use of QNH [code: “To what should I set my altimeter to read your airfield height?”] for takeoff and landing operations. This was done from the time that radio altimeters provided at least some height information that could be taken to replace the height above touchdown provided by using QFE [code: “To what should I set my altimeter to obtain height above your location?” Also, the barometric pressure reported by a particular station]. The impulse to use only QNH is driven by the resulting reduction in need to adjust the altimeter setting. Reduction in the number of times the altimeter setting is changed materially reduces the possibility of error. But there are problems where operators use QFE in an area where the majority use QNH and more particularly in those international operations where users of one system fly to airports where the other system is in use. Although it should be possible to obtain both QNH and QFE altimeter settings, this is not universally the case.

There may not be a solution to this problem. It is similar to the problem of different units for distance and altitude, in that different aviation traditions have established different systems. Use of QFE does give the pilot a direct statement of height above touchdown, which those using QNH can only obtain through a mental computation or comparison of pointer position to a bezel bug set at the touchdown zone (TDZ) elevation. For these reasons instrument approach charts give both altitudes and heights for relevant points in procedures. Use of QNH reduces the number of altimeter setting changes and eliminates the need to make a change during a missed approach, where this would otherwise be necessary.

Both altitude and height information could readily be provided in flight management system (FMS)-equipped aircraft where currently only altitude is provided on the situation display, in addition to the conventional altimeters. Such provision of a direct height above touchdown readout would only require a software change.

Recommendations

Develop rigorous procedures and training in the use of both systems for all flight crews who operate under both systems; and,

There is no doubt that the ideal solution would be to have one system in universal use and that logically this should be the system that calls for fewer changes to the altimeter settings. At the same time, other means of displaying the height above touchdown should be investigated.

Results

In March 1995, the ICAO ANC was informed that the CFIT Task Force would report at a later date on the use of QNH and QFE. Revised ATC procedures have been recommended to the ATC Team.

Action

Recommend that ICAO consider the specification of the use of the QNH reference system for all operations below the transition level/altitude.

Investigate the provision of a direct “height above touchdown” display on aircraft equipped with FMS.

Altimeter setting units

Problem statement

Although international standards call for the use of the hectopascal as the unit for the reporting of atmospheric pressure, the continued use of inches and millimeters of mercury, as well as hectopascals, for reporting atmospheric pressure in different areas of the world, and thus for altimeter setting units, was recognized as likely to continue for some time.

Because of the above differences, specific procedures are used to identify the units used in meteorological reports, but these procedures do not extend to usage in ground-to-air transmissions where the identification of the units is currently optional.

Recommendation

All States should standardize on the use of hectopascals for altimeter settings in accordance with the established international standards, and thus eliminate the potential hazard of mis-setting of the altimeter.

Results

In March 1995 the ICAO ANC was provided with the above recommendation and informed that the CFIT Task Force would be reporting further on this question.

To avoid some errors in altimeter settings resulting from misinterpretation of which units have been provided in a ground-to-air transmission, it is suggested that the unit of measurement be transmitted with the first mention of altimeter setting at international airports. The unit of measure should also be included in automatic terminal information system (ATIS) broadcasts, either voice or datalink. Rigorous procedures and training are necessary where flight crews may be exposed to the use of barometric units other than those to which they are normally accustomed. The use of the term “hex” instead of hectopascal was seen as improving the communication of the altimeter setting between controller and pilot. These questions are also to be discussed by the CFIT Task Force ATC Team.

It has been established that within areas where a specific pressure unit, particularly “inches” is used (and the atmospheric pressure can at times be very low), there is a tendency to set too high a setting through nonrecognition or nonacceptance of the low value. Settings such as 28.98 inches have been mis-set as 29.98 inches, resulting in an altitude/height error of 1,000 feet (305 meters) low. The suggestion in these circumstances is to interpose the word “low” immediately before the pressure setting in ground-to-air transmissions. This proposal has also been referred to the ATC Team.

Action

Re-emphasize the 1994 recommendation and urge States to comply with the international standard for the reporting of atmospheric pressure;

Propose the statement of the applicable pressure unit in the first ground-to-air transmission of an altimeter setting at an international airport and statement of the units in ATIS broadcasts, either voice or datalink;

Propose consideration of the abbreviated term “hex” for the unit “hectopascal” to refer to this unit, which is simpler for users of languages other than English; and,

Propose the interposition of the word “low” before very low altimeter settings, to assist recognition of low settings by flight crew. Actual values to trigger action would need to be determined.

Radio Altimetry

Altitude callout

Problem statement

The team discussed ways in which existing radio altimeter installations could be used to provide terrain clearance information. It was accepted that the widespread operational experience already available on such callouts could provide better guidance on their use than a new simulation program.

Many aircraft have radio altimeters, primarily to support Category II and III operations. However, many operators also employ radio altitude to enhance terrain awareness through a variable combination of crew callouts, automated callouts and associated procedures. These practices have been confirmed through a survey of international operators, who are members of the IATA Flight Operations Advisory Committee (FLOPAC).

It was concluded that use of radio altimetry could enhance terrain awareness and that the full capability of radio altitude information should be exploited. Automated voice callouts of appropriate radio altitudes and associated flight crew procedures should be provided. Some operators have instituted an automated callout at 500 feet (153 meters). This callout, known as a “smart” callout, is arranged to occur only during a nonprecision approach to alert the pilot to proximity of terrain. Use of crew callout, where automated callout was not provided, was also seen as a valuable and unexploited means of enhancement of terrain awareness. Neither automated callouts nor crew callouts will provide protection unless appropriate crew procedures and training are provided.

Recommendations

The radio altitude callout facility should be employed to enhance situational awareness of proximity to terrain. Operators should ensure that the facility is used and appropriate procedures provided. Where altitude callout is not available, or where GPWS is not fitted, a radio altimeter

can be used to provide enhanced situational awareness with the use of appropriate procedures.

Results

The ICAO ANC discussed the question of automated altitude callout when it considered the amendments to the GPWS requirements that have now become part of Annex 6. It was considered that altitude callout was not necessarily a function of the GPWS, but may be provided by other means. In March 1995 the ANC noted that the CFIT Task Force was intending to report further.

Further thinking on the altitude callout has prompted confirmation of this means of enhancement of situational awareness. Since altitude callout can, and is, being provided by some manufacturers by means not associated with the GPWS, a requirement for automated callout should not be associated with the GPWS. It is suggested that automated callout be required as a function to assist in the prevention of CFIT specifically to warn of the proximity of terrain and that the radio altimeter reading should be included in the instrument scan and with the nonprecision instrument approach. The precise detail of the function should be left to the individual operator.

Action

Propose that all aircraft that are required to be equipped with GPWS also be provided with the means to generate automated altitude callouts for initial warning of proximity to terrain and for use during nonprecision instrument approach procedures;

Propose that crew callouts are used in all aircraft not required to be equipped with GPWS, but which are equipped with radio altimeters, for initial warning of proximity to terrain and during the conduct of nonprecision approach procedures; and,

Inform all civil aviation authorities and operators of the necessity for appropriate flight crew procedures and training to support the general introduction of automated and flight crew callouts.

Approach waypoints

Problem statement

With a nominal three-degree slope extending upwards from 50 feet (15 meters) above the runway threshold to at least 2,000 feet (610 meters) above airport elevation, the notion of waypoints along that slope becomes valid.

The first waypoint is located at the intersection of the intermediate segment and the final approach segment where the nominal glide path commences, normally not less than 2,000 feet above airport elevation. Some AIPs now define that point. That point may be above the maximum range of the radio altimeter.

The second and third waypoints are defined exclusively by radio altimeter readout. Because of terrain mapping difficulties, the horizontal position of those waypoints may not be defined. The second point is defined by the radio altimeter indicating 1,000 feet above ground level (AGL). The third is where the radio altimeter indicates 500 feet AGL.

Several major air carriers use radio altimeter heights for an aural alert to the crews with defined crew responses. Examples are 2,500 feet (763 meters, when the radio altimeter comes alive), 1,000 feet and for a nonprecision approach, a so-called “smart call” at 500 feet on the radio altimeter.

Action

Propose that the notion of crew alerting by radio altimeter heights be adopted as standard for use with related cockpit procedures developed by the Operations Group.

Reference

Woodburn, Capt. P. Survey of Radio Altimeter Use for Terrain Awareness by International Air Carriers. FLOPAC, International Air Transport Association (Appendix E).

Use of the Global Navigation Satellite System (GNSS)

Problem statement

Many aircraft are now fitted with GNSS equipment. Although GNSS equipment may not yet be approved as a stand-alone means of navigation, it does provide the flight crew with further data on their location when they have reason to question the availability and/or accuracy of the primary navigation system(s). Such errors or failures may be critical, particularly in the approach-and-landing phase of a flight in difficult terrain.

The use of GNSS should be encouraged to provide back-up navigation information, particularly in the approach-and-landing phase of flight. To achieve this safety benefit, the GNSS output must be displayed in a way that is readily usable by the flight crew and that will alert them to potential navigation errors. Appropriate crew procedures and training will also be required.

Recommendation

The development and availability (of GNSS) should be strongly supported.

Results

In March 1995 the ICAO ANC stressed to States the potential for accuracy and the safety inherent in the GNSS. The ANC also informed three ICAO panels, the Global Navigation Satellite System Panel (GNSSP), the All Weather Operations Panel (AWOP) and the Obstacle Clearance Panel (OCP), of the urgent need for application of GNSS to nonprecision instrument approach procedures.

At the ICAO Special Communications/Operations Divisional Meeting (1995) (SP COM/OPS/95), Montreal, Canada, 27 March to 7 April 1995, the need for the development of GNSS nonprecision instrument approach procedures for the overlay of existing procedures and for new procedures was again stressed. GNSS nonprecision approaches will provide all the detail required to apply the stabilized approach and the three-degree glide path. Implementation of these approach procedures will reduce the dangers in many conventional nonprecision approaches where there is no distance-to-threshold information and those without a final approach fix. Progressive development of the GNSS precision approach capability will enable the elimination of the nonprecision approach in all its forms, except a few circling approaches.

Rapid development and publication of appropriate GNSS nonprecision instrument approach procedures are necessary to reduce the risk of unofficial use of the GNSS navigation capability. There are a large number of GNSS receivers available and in use.

Action

Propose the rapid introduction of specifically designed GNSS nonprecision approach procedures where an appropriate level of accuracy is available that conforms to the use of the stabilized approach and the three-degree glide path with a defined final approach point. Glide path angles steeper than three degrees may be used if necessary, up to the maximum permitted.

References

ICAO Special Communications/Operations Divisional Meeting (1995) Report

Slatter, R.T. "Role of CNSS/ATM in Reducing CFIT in the Terminal Area." IATA GLOBAL NAVCOM 1995, Montreal, Canada, 25 September 1995.

ICAO. *Procedures for Air Navigation Services, Aircraft Operations* (PANS-OPS, Doc 8168), Volumes I and II.

ICAO Obstacle Clearance Panel, 10th Meeting Report.

Excessive-bank-angle Warning

Problem statement

The Aircraft Equipment Team is convinced that excessive-bank-angle warning would help avoid CFIT and loss-of-control accidents. Aircraft have been destroyed in accidents when excessive bank angles developed without detection by the flight crew. High undetected bank angles have resulted in loss of vertical control. The risk of future occurrences remains high. Excessive-bank-angle occurrences have been classed with CFIT occurrences because GPWS models from the MK V have provided an excessive-bank-angle warning facility. Excessive-bank-angle warning is provided by some airframe manufacturers independently of the GPWS.

Results

The ICAO ANC discussed the question of excessive-bank-angle warning when it considered the amendments to the GPWS requirements that have now become part of Annex 6. It was considered that this warning was not necessarily a GPWS function, but may be provided by other means. In March 1995 the ANC noted that the CFIT Task Force was intending to include the excessive-bank-angle warning in its next report.

Many of these incidents occur because of lack of tactile sensory feedback. These sensations are often masked by the inadvertent lowering of the aircraft's nose with subsequent altitude loss. Further analysis of excursions in bank angle indicates that these occurrences have had various causes:

- Undetected and uncommanded roll with autoflight engaged;
- Looking outside the cockpit at inadequate visual reference during low altitude maneuvers;
- Vertigo; and,
- Failed attitude reference display.

It is therefore proposed that means be provided to alert the flight crew to an excessive bank angle, particularly when maneuvering close to terrain. Actual values at which the warning should activate depend on the phase of flight. The function should involve:

- Built-in maximum-bank limiters in fly-by-wire aircraft;
- Enhanced/emphasized high bank angles on the attitude display; and,
- Visual or aural alert of high or unusual roll angles.

Action

Propose that all aircraft required to be equipped with GPWS also be provided with the means to generate an excessive-bank-angle warning.

Reference

Partial List of Excessive-bank-angle CFIT Accidents/Incidents (Appendix C).

Head-up Display (HUD)

Problem statement

The team believed that the head-up display (HUD) may be of benefit in all phases of flight, particularly in the final approach phase of nonprecision instrument approaches and visual approaches. The CFIT Working Group is aware of the increasing use of HUDs for air carrier operations and knows why operators with fully automatic instrument approach systems do not want to fit HUDs.

Recommendations

HUD benefits should be publicized more widely. Their use should be encouraged and development should be continued to eliminate known limitations. Further investigations that could demonstrate whether or not the use of HUDs has the potential to reduce the CFIT risk are recommended.

Results

In March 1995 the ICAO ANC noted the CFIT Task Force's support for HUD and the HUD's potential to contribute to safety in nonprecision approach and visual approach and landings.

Action

Such developments should be strongly supported.

References

Flight Safety Digest (September 1991).

Head-up Guidance System Technology (HGST) — A Powerful Tool for Accident Prevention. Project Report FSF/SP-91/01. July 1991.

Enhanced and Synthetic Vision

Problem statement

The team was aware of developments in sensor and data base technologies in the field of enhanced and synthetic vision systems. Such systems attempt to give the flight crew an enhanced image of the external environment, or a completely synthetic reproduction of the external environment, and may have the potential to reduce the CFIT risk. However, many unresolved issues exist with respect to these systems. The CFIT Equipment Team recommends any activities that could demonstrate and quantify whether such systems are, or would be, able to offer safety benefits.

Recommendation

Such developments should be strongly supported.

Results

In March 1995 the ICAO ANC noted the support for the development and introduction into service of enhanced and synthetic vision systems.

Minimum Safe Altitude Warning System (MSAW)

Problem statement

This system is used to assist in the detection of inadvertent flight towards terrain. It is the understanding of the Team that MSAW can be readily implemented at little cost.

Action

Remind the ATC team of the recommendations for use of MSAW and other means of alerting ATC to the terrain proximity of aircraft under their control; and,

Present proposals to the ICAO Air Navigation Commission and individual administrations to make MSAW a standard for CFIT prevention.

Visual Approach Slope Indicator System (VASIS)

Problem statement

The VASIS display is sometimes disabled during certain weather conditions.

Recommendation

VASIS signals are accepted pilot aids. The use of VASIS should be encouraged under all approach conditions. They should not be turned off at any time.

Action

Recommend to ICAO that VASIS installation and continuous operation be supported.

Communication Blocking

Problem statement

The CFIT Working Group is aware that the inability to communicate because of such factors as “stuck” microphones, failures of flight crew to release the press-to-talk (PTT) switch, PTT switch failures and other disruptions have been present in a number of incidents. This can hamper or prevent the transfer of crucial information between ATC and crew in a timely manner.

Recommendation

The CFIT Working Group encourages the use of any appropriate means (which has the required level of integrity and reliability) that restores normal communications and/or prevents communications blockage.

Conclusions

CFIT Accident Data Base

- Continuous measurement of the incident/accident rate is essential to assess any changes as a result of CFIT prevention activities.

Chart Presentation

- Improved charting should be made available to every pilot on every flight. This may be the only CFIT prevention tool available.

Ground-proximity Warning System (GPWS)

- Improved systems are available.
- The trained pilot is an essential component of any system.

Approach Procedure Design

- Nonprecision approaches show high CFIT risk.
- Simplifying them reduces the risk.

Vertical Navigation

- Errors in vertical navigation have many causes.
- Each of the suggested actions reduces the risk.

Use of GNSS\GPS

- Lateral navigational errors could be reduced by reference to GPS/GNSS

Excessive-bank-angle Warning

- Inappropriate bank angles at low altitudes contribute to CFIT accidents.
- Alerting or prevention systems would reduce the incidence.

ICAO Actions

- Only international standards will reduce the CFIT accident rate to the target level. Application of international standards in domestic operations is seen as a major step towards reduction of CFIT rates.

Other Topics Considered

- There are many systems that could contribute to the reduction of the CFIT rate. Only those that are likely within the next five years were considered.

David E. Walker
Chairman, CFIT Aircraft Equipment Team
5125 Patricia, Montreal, QC
Canada, H4V 1Y9
Phone: (514) 482-9583
Fax: (514) 481-3273
Internet 75346.1331@compuserve.com

APPENDIX A

CFIT ACCIDENTS AND RISKS FOR UNITED STATES AIRLINES
LARGE COMMERCIAL JETS

TYPE OF CFIT LOSS		CFIT ACCIDENTS AND RISK				REDUCTION () OR INCREASE (+) TIMES
		PRE-GPWS 1960 thru 1975		POST-GPWS 1976 thru 1994		
Initial Climb	Accelerating Descent	1	0.03	0	<0.001	>-100
Into mountainous terrain Landing short	Climb out Initial approach Missed approach	6	0.17	4	0.03	-5.7
	Note configured to land	5	0.14	0	<0.01	-140
	Configured to land/no glideslope	5	0.14	6	0.06	-2.3
	Below glideslope	8	0.22	0	0.001	-220
	Excessive descent rate	5	0.14	0	0.001	-140
TOTAL CFIT ACCIDENTS & RISKS		30	0.85 x 10	10**	0.09 x 10 ⁻⁶ *	-9.6
	Flight segments	35 x 10		108 x 10		+3.1
	Aircraft numbers	2 800 in 1976		4 800 in 1994		+1.7

CFIT Risk 1990 thru 1994 (5 years) 0.028 x 10⁻ flights with 7- x 10 flights per year

CFIT Risk 1985 thru 1994 (10 years) 0.074 x 10⁻ flights

In the United States (2) 0.033 x 10 flights

Outside the United States (3) 0.44 x 10 flights

If aircraft had been fitted with MK II or better, losses would have been reduced probably to 6 (0.055 x 10⁻).

If aircraft has been fitted with MK V/VI/VII system with "smart" altitude callouts, the losses would have probably been reduced to 3 (0.03 x 10⁻).

10 CFIT Accidents. One accident with NO GPWS installed. One accident with glideslope receiver failure. Nine accidents equipped with MK I GPWS.

APPENDIX B

CORPORATE, REGIONAL AND AIR TAXI CFIT ACCIDENTS

1994

OPERATION	DATE	PLACE, AIRCRAFT TYPE	COMMENTS	FATALITIES
Regional	9 Jan	Athens, Greece DO-228	Hit ridge-powerlines 7 NM from runway, VOR-DME 18L.	- -
Freight	14 Jan	Sydney, Australia AC 690	Flew into sea 10 NM short at night, rwy 34.	1
Positioning	18 Jan	Kinshasa, Zaire LJ-24D	Hit short 10 NM at night, visual 24.	2
Charter	24 Jan	Attenrhein, Switzerland Ce-425	Flew into lake - 2 NM, final 10.	5
Positioning	27 Jan	Meadow Lake, Sask. IAI-1124	Hit 2 NM SE - stall?, circling 26.	2
Scheduled	23 Feb	Tingo Maria, Peru Yak-40	Flew into mountain FL131, NDB departure.	31
Positioning	7 March	Virginia AC-690	Hit trees on approach	1
Freight	9 March	Australia SA-226	Hit short on approach	1
Business	23 March	Bogota, Colombia Ce-VI	Hit hillside, initial approach.	4
Scheduled	6 April	Latacunga, Ecuador DHC-6	Hit 13,400 mtn 300' below crest, premature descent.	17
Regional	25 April	Nangapinoh, Indonesia BN-2A	Hit mtn at 5400' level, initial descent.	10
Regional	27 April	Stratford, CT PA-31T	Hit 3 NM short, final 06.	8
Corporate	7 May	Zaire Be-200	Hit short of runway	9
Medevac	26 May	Papeete, Tahiti Mu 2B	Hit short by 4 NM on ILS Rwy 04 approach	5
Ferry	27 May	Germany Be-90C	Hit in steep turn back to runway	1
Medevac	31 May	Thompson, Manitoba Merlin II	Hit FAF NB 3.4 short, B/C LOC. rwy 33.	2
Regional	13 June	Uruapan, Mexico Metro II	Hit terrain while maneuvering for 3rd approach.	9
Scheduled	18 June	Palu, Indonesia F-27	Hit mtn 3-1/2 NM short, initial approach.	12
Charter	19 June	Washington DC-Dulles LJ-25D	Hit 1-1/2 NM short, ILS 1R.	12
Charter	26 June	Abidjan, Ivory Coast F-27	Hit 2-1/4 NM short, VOR/DME 21	17
Government	9 July	Kulu, India Be-200	Hit mtn 7 NM SW of airport, NDB.	13
Charter	17 July	Fort de France BN-2B	Hit at 2780' mtn, 15' below crest, 6 NM, VOR/DME.	6
Private	24 July	Portsmouth, OH PA-32T	Hit trees on rising terrain, departure rwy 18.	5 of 6
Gov t (Drug Enforce)	27 Aug	Pucalpa, Peru CASA-212	Hit hill, NDB/VOR.	5
Charter	13 Sept	Abuja, Nigeria DHC-6	Hit 5 NM short, VOR-DME 22.	2 of 5
Corporate	17 Sept	Texas HS-125	Hit Trees on approach	- -
Private	10 Oct	Missouri AC 690	Hit into groun in initial climb	1
Freight	29 Oct	Ust-Ilimsk, Russia AN-12	Hit short on approach by 1-2 NM at night.	21

CFIT Aircraft Equipment Team

OPERATION	DATE	PLACE	AIRCRAFT TYPE	COMMENTS	FATALITIES
Charter, Freight	4 Nov	Kebu, Nabire, New Guinea	DHC-6	Hit hill, approach.	4
Air Taxi	19 Nov	Saumer, France	Be-C90	Hit ground while circling after successful locator; (NDB) approach.	7
Air Taxi	22 Nov	Bolvovig, New Guinea	BN2A-2D	Hit hillside on initial approach.	7
Scheduled	10 Dec	Koyuk, Alaska	Ce-402	Hit short on approach.	5
Business	16 Dec	Michigan	Ce-501	Hit short into approach lights	--
Scheduled	17 Dec	Tabubil, Papua N. Guinea	DHC-6	Hit ridge enroute to Selbang (25 miles east) on initial climb.	2
(3) Large Turboprop		(7) 10 Seat Turboprop		No GPWS equipment on any of the above aircraft	
(6) 10 to 30 Seat Turboprop		(5) 6 Seat Jet			

APPENDIX B (Continued)

1993

OPERATION	DATE	PLACE	AIRCRAFT TYPE	COMMENTS	FATALITIES
Regional-Schd	6 Jan	Paris, France	DHC-8	Hit short while repositioning ILS 27 to ILS 28	4
Air Taxi	8 Jan	Hermosillo, Mexico	L-35A	Hit Mountain on approach to VOR 23	9
Private	29 Jan	Marfa, TX	Be-90	Circling to runway 12, IMC after VOR 30	0 of 8
Regional-Schd	30 Jan	Ackh, Inur, Malaysia	SC-7	Hit terrain en route	16
Air Taxi	7 Feb	Iquacu, Brazil	Be-90	Hit 0.6 NM short - IMC; heavy rain	6
Air Taxi	8 Feb	Lima, Peru	PA-42-720	Hit mountain initial descent	6
AT-Non Sched	27 Feb	Rio de Janeiro	L-31	Hit short by 300 feet	--
Air Taxi	18 Mar	Trijillo, Peru	Be-90E	Hit mountain initial descent 50NM short	4
Air Taxi	19 Mar	Dagali, Norway	Be-200	Hit 3 NM short LOC/DME 26, night	3 of 7
Reg l-NonSchd	23 Mar	Cuiaba, Brazil	EMB 110	Hit terrain on climb out	6
Private-Trng	1 April	Blountville, Texas	SA-226T	Undershoot outside outer marker	4
Air Taxi-Med.	6 April	Casper, WY	MU-2B-35	Hit terrain on DME Arc ILS 8, night	4
Private	1 May	Mount Ida, AR	Be-90	Hit Mt. Ida (3 NM short). Climb IMC	2
Air Taxi-Trng	25 May	Sante Fe, NM	SA-226T	Hit hill while circling to Rwy 15.5 NM short at night	4
Reg Cargo NS	5 June	El Yo Pal, Colombia	DHC-6	Hit short while circling	2
Regional-Schd	11 June	Young, Australia	PA-31	Hit rising ground while circling after ND approach	7
Reg-Carg-Sch	25 June	Atinues, Namiba	Be-200	Hit terrain on missed approach	3
Government	15 July	Bombay, India	Be-90	Hit hill on approach IMC	4
Regional-Schd	31 July	Bharatpur, Nepal	DO-228	Hit mountain on initial approach	19
Air Taxi-Med.	7 Aug	Augusta, GA	Be-90	Hit 1-1/2 NM short on approach IMC to ILS 17	4
AT-Positioning	17 Aug	Hartford, CT	SA-226T	Hit 1/3 NM short IMC to Rwy 02	2
AT-Positioning	27 Sept	Lansing, MI	Be-300	Hit 2 NM after 7.0 IMC turning	2
Regional-Schd	19 Oct	Orchid Is., Taiwan	DO-228	Undershoot	--
Regional-NS	25 Oct	Franz Josef Glacier, NZ	Nomad	Hit Glacier VMC into IMC	9
Gov t-FAA	26 Oct	Winchester, VA	Be-300	Hit terrain while awaiting IFR clearance	3
Regional-Schd	27 Oct	Namos, Norway	DHC-6	Hit 3 NM short on NDB approach	12
Regional-Schd	1 Dec	Hibbing, MN	BAe JS-31	Hit 3 NM short on LOC (B/C) Rwy 13	18
Regional-Schd	10 Dec	Sandy Lake, Ontario	HS 748	Climbing turn, back into terrain	7
AT-Positioning	30 Dec	Dijon, France	Be-90	Hit short on approach IMC	1

(2) Large Turboprop

(16) 10 Seat Prop. Except for DHC-8, there was no GPWS on any of the above aircraft.

(9) 10 to 30 Seat Turboprop

(2) 6 Seat Jet

CFIT Aircraft Equipment Team

APPENDIX B (Continued)

1992

OPERATION	DATE	PLACE	AIRCRAFT TYPE	COMMENTS	FATALITIES
Regional-Schd	3 Jan	Saranac Lake, NY	Be-1900	Hit short at FAF on ILS 23 IMC.	2F/2S
Private	11 Feb	Lakeland, FL	Ce-425	Hit short of runway 05 IMC.	1
Charter	16 Feb	Big Bear, CA	PA-31T	Hit terrain at 6740 7 NM east of airport.	7
Private	5 Mar	New Castle, CO	MU-2B	Hit mtn - LOC/DME "A" Gear Down; Approach flaps 10-1/2 NM short.	6
Private	29 Mar	Taos, NM	AC-390	Hit rising terrain on climb out; IMC night 3940 (visual); radio altimeter installed.	1, 5S
State Aircraft	9 April	St. Augustine, FL	Be-90	Hit short on VOR approach 007: 10 EDT IMC.	2
Regional-Tour	22 April	Maui, Hawaii	Be-18	Hit mtn enroute.	9
Regional-Schd	8 June	Anniston, AL	Be-99	Hit terrain during LOC 5 approach.	3F/2S
Personal	24 June	Alamagordo, NM	MU-2B	Hit mtn VMC during climbout 12:21 MDT - Night.	6
Regional-Schd	24 July	Ambeu, Indonesia	Vickers Viscount	Hit mtn during initial approach ILS/04.	71
Personal	13 Aug	Osway, MO	PA-31	Hit short rwy 32-IMC.	--
Personal	4 Sept	Longton, KS	PA-42	Hit wires on approach.	--
Government	19 Oct	Pesqueria, Mex (Monterey)	AC-680T	Hit terrain during climbout IMC.	6
Comm/Air Taxi	31 Oct	Grand Junction, CO	PA-42	Hit mtn 10 NM north RNAV-Cleared to ILS rwy 11. "Macks" int. eastbound 9400 -7800 cliff; IMC day 0315.	3
National Guard	11 Nov	Juneau, AK	Be-200	Hit mtn LOC/DME 20+ NM from runway.	8
Government	10 Dec	Quito, Ecuador	Sabreliner	Hit 3 NM short during VOR/ILS 35 approach.	12
Regional-Schd	13 Dec	Goma, Zaire	F-27	Hit short into terrain during initial approach VOR/DME 36.	37
Government	22 Dec	Quito, Ecuador	PA-31	Hit 3 NM short during VOR/ILS 35 approach.	5

(2) Large Turboprop (13) 10 Seat Prop No GPWS installed on any of the above aircraft.
 (2) 10 to 30 Seat Turboprop (1) 6 Seat Jet

CFIT Aircraft Equipment Team

APPENDIX B (Continued)

1991

OPERATION	DATE	PLACE	AIRCRAFT TYPE	COMMENTS	FATALITIES
Corporate	11 Jan	Belo Horizontes, Brazil	LJ-25	Hit 2 NM short.	5
Air Taxi-Ferry	8 Feb	Stansted, UK	Be-200	Hit 2-1/2 NM short of the runway; possible altimeter error.	2
Corporate	12 Feb	Uganda, Kenya	HS-125	Hit mtn on initial approach.	3
Air Taxi	15 Mar	Brown Fld, CA	HS-125	Hit mtn on departure 8L.	10
Corporate	18 Mar	Brasilia, Brazil	LJ-25	Hit short.	4
Corporate	21 May	Bauchi, Nigeria	Ce-550	Hit short.	3
Corporate	17 June	Caracas, Venezuela	G-II	Hit 5 NM short to rwy 10.	4
Corporate	4 Sept	Kota Kinabalu, Malaysia	G-II	Hit mtn during missed approach.	12
Charter	17 Sept	Djibouti	L-100	Hit mtn VMC during initial approach.	4
Corporate	25 Sept	Holtenou Klel, Germany	DS-20	Missed approach.	1
Regional-Schd	27 Sept	Guadalcanal, Sol.	DHC-6	Hit mtn enroute.	15
Corporate	8 Oct	Hanover, Germany	Ce-425	Hit short on ILS 27R.	7
Air Taxi	22 Nov	Romeo, MI	Be-100	Hit 3 NM short on VOR/DME approach, IMC-fog.	4
Corporate	27 Nov	Paloma, Majorca	Be-400	Hit 1/4 NM short.	- -
Corporate	30 Nov	Kelso, WA	AC 690	Hit mtn 13 NM short.	5/1S
Corporate	11 Dec	Rome, GA	Be-400	Hit mtn on departure.	9

(1) Large Turboprop (5) 10 Seat Prop No GPWS installed on any of the above aircraft.

(2) 10 to 30 Seat Turboprop (8) 6 Seat Jet

CFIT Aircraft Equipment Team

APPENDIX B (Continued)

1990

OPERATION	DATE	PLACE	AIRCRAFT TYPE	COMMENTS	FATALITIES
Regional-Schd	15 Jan	Elko, Nevada	Metro III	Hit mtn at FAF VOR-A.	4-5/16
Regional-Schd	16 Jan	San Jose, Costa Rica	CASA	Hit mtn on departure.	23
Air Taxi-Cargo	17 Jan	Denver to Montrose, CO	Ce-208A	Hit 50 below Mt. Massive (14,221) near Leadville, CO.	1
Corporate	17 Jan	West Point, MS	Be-400	Undershoot.	--
Corporate	19 Jan	Little Rock, AR	G-II	Hit short on ILS.	7
Air Taxi-Cargo	29 Jan	Williston, VT	Ce-208B	Hit trees, power lines on climb out at major IMC.	2
Air Taxi-Cargo	29 Jan	Schuyler Falls, NY	Ce-208B	Hit 1-1/2 NM beyond rwy 19 during climb out IMC, night.	1
Schd-Freight	21 Mar	Tegucigalpa, Honduras	L-188	Hit mtn 6 NM short VOR/DME rwy 1.	3
Business	27 Mar	Uvalde, TX	Be-100	Hit terrain 4 NM south of field on approach in IMC-night.	--
Regional-Schd	20 April	Moosonee, Ontario	Be-99	Hit 7 NM short on VOR rwy 24.	1 of 4
Air Taxi	28 April	Tamanrasset, Algeria	Be-90A	Hit 4 NM short on approach.	6
Regional-Schd	4 May	Wilmington, NC	GN-24	Hit short on B/C Loc 16.	2
Air Taxi	11 May	Cairns, Australia	Ce-500	Hit mtn on initial approach.	11
Air Taxi	13 Aug	Cozuneil, Mexico	AC 1121	Undershoot.	1
Air Taxi	11 Sept	New Mexico	MS-760?	Hit mtn on departure.	2
Business	22 Sept	White Plains, NY	AC 690B	Hit short by 3 NM in IMC.	0 of 6
Air Taxi	24 Sept	San Luis Obispo, CA	Ce-500	Hit short on approach LOC 11.	4
Corporate	21 Nov	Keller Jock, Australia	Be-200	Initial approach.	3
Air Taxi	29 Nov	Sebring, FL	Ce-550	Undershot on approach rwy 11.	--
Business	30 Nov	Kelso, WA	AC-690A	Hit short by 8 NM night on initial approach into mountain.	5 of 6
Air Taxi-Cargo	21 Dec	Cold Bay, AK	Ce-208	Hit mountain enroute.	1

(1) Large Turboprop (12) 10 Seat Prop No GPWS installed on any of the above aircraft.

(3) 10 to 30 Seat Turboprop (5) 6 Seat Jet

CFIT Aircraft Equipment Team

APPENDIX B (Continued)

1989

OPERATION	DATE	PLACE	AIRCRAFT TYPE	COMMENTS	FATALITIES
Private	2 Jan	Mansfield, OH			
Private	7 Jan	Paducah, KY	Be-90	Hit mtn on departure.	3 of 15
Schd Freight	12 Jan	Dayton, OH	M-2B	Hit 8 NM short during an ILS 24 approach circle for 23. Night, IMC.	4
Air Taxi	12 Jan	Caracas, Venezuela	Be-200	Hit terrain while diverting in low cloud.	2
Charter	19 Feb	Orange County, CA	Ce-404	Hit mtn 20 NM short.	10
Air Taxi	23 Feb	Altenshein, Lake Contance, Switzerland	AC-690	Hit short to rwy 10. VMC into IMC.	11
Air Taxi	24 Feb	Helsinki, Finland	SA-226T	Hit short on ILS approach IMC.	6 of 7
Regional-Schd	10 April	Valence, France	FH-27T	Hit mtn, initial approach.	22
Air Taxi-Ferry	10 May	Azusa, CA	Be-200	Hit San Gabriel Mountain at 7300 level (departed Santa Monica).	1
Corporate	29 June	Cartersville, GA	DA-20	Initial climb, shallow into terrain.	2
Regional	31 July	Auckland, New Zealand	CV-580	Hit during initial climb.	34
Regional-Schd	3 Aug	Samos, Greece	SD-330	Hit mtn enroute.	16
Charter	7 Aug	Gambella, Ethiopia	DHC-6	Hit power lines - fog.	3 of 7
Air Taxi-Med	21 Aug	Mayfield, NY	Be-100	Hit 1/4 NM short at night IMC.	6
Business	15 Sept	Terrace, BC	Metro III	Missed approach LDA/DME.	7
Regional-Schd	26 Sept	Hurdle Mills, NC	Ce-550	Hit 2-1/2 NM short on approach.	2
Regional-Schd	28 Oct	Molokai, Hawaii	DHC-6	Hit mtn enroute.	20
Corporate	7 Nov	Ribeiro Das, Nevez	LJ	Hit hill on approach.	5
Private	2 Dec	Ruidoso, NM	Be-90	Hit short in procedure turn NDB approach IMC.	2
Air Taxi-Positioning	22 Dec	Beluga River, Alaska	PA-31T	Hit 8 NM short.	--
Regional-Schd	26 Dec	Pasco, WA	BAe JS-31	Hit short on ILS 21R.	4

(3) Large Turboprop (10) 10 Seat Prop No GPWS installed on any of the above aircraft.

(6) 10 to 30 Seat Turboprop (2) 6 Seat Jet

APPENDIX C

PARTIAL LIST OF EXCESSIVE-BANK-ANGLE CFIT ACCIDENTS/INCIDENTS

DATE	PLACE	AIRCRAFT TYPE	PHASE OF FLIGHT	CIRCUMSTANCES	FATALITIES
Various 1992 93	World-wide	Glass cockpit	En-route	Slow undetected rolls	--
6 June 92	Panama	B737-200	En-route	Slow undetected roll to 90 degrees believed to be ADI or autopilot	47
15 Feb 92	Toledo, OH	DC8-63	Missed approach	Slow undetected roll; autopilot; night	4
12 Dec 91	NWT Canada	B747-100	En-route	Slow undetected roll; autopilot; FL310 to FL190 recovery	--
1990	Montreal - Paris	B747-200	En-route	Slow undetected roll (71 degrees)	--
30 April 89	Miami - London	B747-200	En-route	Slow undetected roll (52 degrees)	--
12 Jan 89	Dayton OH	HS-748	Take-off climb	Slow roll to 50 degrees for turn during climb out; night	2
28 Oct 88	Paris	B747-100	Final	Visual transition, alignment to runway at night, overbank to 17 degrees at 150 ft.	--*
19 Feb 99	Raleigh-Durham	Metro III	Take-off climb	Expedited departure, overbanked to 45 degrees at 300 ft.	12
Dec 87	Edmonton, Canada	DC8-63F	Final	Visual transition at night to align with runway. Overbanked to 15 deg. at 150 ft.	--*
Nov 86	London	B747-200	Final	Visual transition at night to align with runway	--*
12 Nov 80	Cairo	C-141	Turning base to final	Overbanked at night; visual; no lights on ground	13
1 Jan 87	Bombay	B747	Departure climb	Rolled to 80 degrees at 1400 ft; night ADI failure, no flag	213
Sept 77	Geneva	B747	Departure climb	Roll, slow but detected in time by FO; ADI failure, no flag	--

*Significant change

APPENDIX D
REPORT ON CFIT ACCIDENT DATA

By R. Khatwa, National Aerospace Laboratory (NLR) Flight Division,
Amsterdam, Netherlands

1. CFIT accidents are those in which an otherwise serviceable aircraft, under the control of the crew, is flown into terrain, obstacles or water with no prior awareness on the part of the crew of the impending disaster. Inadvertent flight into ground or water has been a problem since the early days of aviation. Although many of the accidents have occurred in the less developed areas of the world, regions such as Western Europe and North America are not immune from the CFIT threat.

Despite all the anti-CFIT measures taken to date, CFIT accidents continue to occur at an unacceptable rate, and a number of common factors have continued to contribute to CFIT accidents. The list is long and the examples include nonstandard phraseology, noncompliance with procedures, visual illusions, confusing charts, crew fatigue, misreading/mis-setting altimeter, disabling GPWS, nonoptimal approach procedure design and ATC errors.

It is crucial to realize that various elements of the aviation infrastructure outside the flight deck can contribute to the cause of the accidents by virtue of their adverse effects on flight crew performance. Crews have often found themselves in the final link in the chain of events that lead to a CFIT accident. An NLR CFIT taxonomy suggests that the combination of variables that normally contribute to a CFIT accident belong to at least two of the following groups: flight crew, environment, approach, ATC aircraft equipment and organizational and regulatory factors. A reduction in the CFIT risk will therefore require a concentrated effort from all elements of the industry.

2. CFIT accidents are generally associated with a high level of kinetic energy, and the result is usually the complete destruction of the aircraft and the loss of almost all the occupants. ICAO statistics for commercial and general aviation operations indicate that for the period 1978-1991 there were 260 CFIT accidents resulting in 5,500 casualties. Both older-generation and newer glass-cockpit aircraft have been involved in the accidents, although data suggest that the risk appears to be higher for the former category.

Most accidents occurred to aircraft engaged in domestic commercial operations. For one particular State alone, between 1976 and 1990 there were 171 CFIT accidents to aircraft engaged in domestic operations. This averages one CFIT accident approximately every four weeks for 14 years for that State alone. A significant proportion of the accidents occurred within a radius of 25 nautical miles of the threshold and on the runway approach path. Data indicate that although the vertical profile is a major source of error, many accident flight descent paths were approximately parallel to a nominal three degree glide path. The absolute number of accidents involving nonprecision approaches appears to be exceptionally high. A large percentage occur during VOR-DEM/LOC-DME approaches. IMC or night IMC conditions are commonly associated with CFIT accidents. It is also evident that a significant number of crews had received little, if any, training specific to recovery procedures.

APPENDIX E

AIRLINE/IATA INPUT — EXTRACTS FROM THE IATA FLOPAC SURVEY OF MEMBERS INTO THE VALUE AND USE OF RADIO ALTIMETERS TO ENHANCE TERRAIN AWARENESS

This survey was completed by senior management pilot representatives affiliated with most of the world's international airlines.

CONCLUSIONS

- There was unanimous consensus that radio altimeters improve terrain awareness.
- There was very strong support for selected radio altitudes to be properly integrated within flight crew procedures and supported by automatic voice callouts.
- Nearly all airlines were aware of and intended pursuing the provision of superior radio altimeter features, to enhance terrain awareness.

British Airways — Stabilized Approach Criteria

- Fleet-specific criteria for desired speed/configuration at 1,000 feet radio altimeter are promulgated, and consideration should be given to a go-around in the event that the 1,000-foot criteria are not achieved.
- On all approaches, the aircraft must be stabilized at 500 feet radio altitude in the planned landing configuration, the glide slope or correct vertical profile must be established with approach power set and indicated airspeed no more than the target threshold speed plus 20 knots. If these criteria are not achieved, an immediate go-around must be carried out.

ICAO

Amendments to Annex 6, Parts I and II

Allied Signal/D. Bateman

- CFIT Accidents by Type of Instrument Procedure, Commercial Jet Aircraft, Last Six Years, July 1988 to July 1994.
- Map location of 40 CFIT Accidents/Incidents from the Runway Threshold Vertical.

APPENDIX F

TAKING THE "NON" OUT OF THE NONPRECISION APPROACH

By Capt. D.E. Walker

The nonprecision approach is the culprit in most CFIT accidents. The point of impact for most CFIT accidents is in line with the intended runway for landing, but anywhere from one to several miles away from the runway. Several aspects of the nonprecision approach contribute to the risk of a CFIT accident short of the runway. The very idea of a nonprecision approach providing no guidance to the pilot in the vertical plane is an anathema. What steps can we take to reduce the risk of this sort of CFIT? By providing precise guidance to the pilot conducting the nonprecision approach? How can we do that?

The first and most obvious step is to provide the pilot with a standard descent slope. Many, if not most, nonprecision approaches provide crossing altitudes at the final approach fix (FAF) that would require a descent path of less than the standard three degrees. There is no minimum approach slope and some nonprecision approaches show a possible descent profile of less than one degree.

Some nonprecision approach charts show the altitude at which a three-degree slope crosses the FAF. In addition, those charts often display the recommended descent rates required to maintain that profile. The pilot is trained to intercept and descend on that three-degree profile. His nonprecision descent has now been made more precise.

Raising the crossing altitude at the final approach fix to establish a three-degree slope would also reduce the number of steps now common during a nonprecision approach. Pilots descending at the wrong step point is a frequent factor in the aircraft colliding with terrain well short of the runway. This is a major cause of CFIT accidents. These inappropriate descents usually result from some sort of navigation blunder.

The often catastrophic result of a navigation blunder may be averted, provided there is some means of alerting the pilot to that error. GPWSs alert the pilot to a descent that is excessively steep. They provide no warning to a pilot descending towards an airport that is not where he expects it to be. The radio altimeter with its audio height callout is used by many operators to alert the pilot to terrain proximity. Some of these devices are being used with so called "smart callouts," which alert the pilot to 500 feet above terrain whenever a nonprecision approach is under way. That is a very worthwhile feature. Its warning comes late, but better late than never. What additional alert would we wish from such a device?

Usually, a nonprecision approach penetrates 1,000 feet above terrain only after passing the FAF. This penetration of the 1,000 feet above terrain will occur at an easily defined point on the three-degree slope from the FAF to the runway. That point should be marked on all nonprecision approach charts. A tentative name of terrain proximity point or TPP is suggested. It is the first opportunity that the pilot has to confirm that vertical tracking is as desired and that the aircraft is actually on the three-degree slope to the runway. Having the radio altimeter system call out when the 1,000-foot AGL veneer is penetrated (TPP) should be time for the pilot to confirm that the aircraft is at the position defined on his chart for penetrating that 1,000-foot veneer on the desired three degree slope. It is our first opportunity to confirm our vertical navigation with reference to underlying terrain.

Summarizing, we want a standard descent profile of nominally three degrees established for all nonprecision approaches. We need to have that slope published on all nonprecision approach charts. Pilots need to be trained to fly that standard descent profile for all, rather than just precision, approaches. Some means of alerting the pilot to his position relative to the desired profile is required. This alert should occur before the aircraft becomes too close to terrain.

I suggest that this combination will do much to reduce the number of aircraft impacting in the final approach zone. These concepts were presented to the CFIT ATC working group meeting in Washington. I propose that they become the principal focus our next meeting of the aircraft equipment group.

APPENDIX G

1. TERRAIN DATA INTEGRITY REQUIREMENTS (from AlliedSignal sources)

The required integrity (accuracy) of terrain data depends on its intended use and purpose. Four levels of integrity are:

- **Level 1** Terrain data that are used for navigation, three axis guidance + display with aircraft performance purposes. Its accuracy is generally ± 10 meters. Usage: typical examples would be military attack aircraft using terrain for tactical advantages and helicopters.
- **Level 2** Terrain data that are used for auto-correlation to update inertial navigation purposes and lateral guidance. Its accuracy is generally ± 30 metres.
- **Level 3** Terrain data that are used for supplemental terrain awareness purposes, indication, and relatively crude prediction purposes. Typical accuracy requirements are $\pm 1/2$ Nautical Mile to ± 8 NM, depending on proximity to an airport.
- **Level 4** (Lowest Integrity) Terrain data that are used for supplemental secondary applications transparent to the pilot or other systems. Its integrity is typically ± 1 NM accuracy and elevations ± 300 feet. One application is "Envelope Modulation" features found in GPWS.

2. FAA Letter, Jan. 11, 1995

"Operational Approval of Stabilized Instrument Approach Procedures for Flight Management/Guidance System Equipped Aircraft."

3. Extract from KLM FAX, 19 Aug. 1994

"KLM tries to provide a stabilized nonprecision final approach even if no DME facility is available, e.g., by using an outbound timing from a navaid. ...

"We also took notice of your article in the *ICAO Journal* and as you may have guessed, we fully agree with it. ...

"We think that ICAO should bring pressure to bear on States in order to persuade them to stop publishing DME stepdown nonprecision approaches, for reasons of safety."

4. Flight Safety Foundation

Safety Alert. June 1993.

Schwartz, D. *FSF CFIT Task Force Flight Crew Training & Procedures Work Group: Report*. 1995.

CFIT Awareness Video.

FSF CFIT Checklist.

FSF *Head-up Guidance System Technology (HGST) — A Powerful Tool for Accident Prevention*. Project Report FSF/SP-91/01. July 1991.

5. Transport Canada Video, "Preventing CFIT Accidents."

—END—